Propagation Model Development & Comparisons

Outputs

- Improvement of the effective height algorithm in the ITS Irregular Terrain Model (ITM).

Propagation model development in FY 2004 focused on improving the effective height algorithm in the ITS Irregular Terrain Model (ITM). Radio propagation predictions made using the ITM are highly influenced by the effective heights of the terminals. The effective heights are used to compute several intermediate quantities that may have a large impact on the prediction.

To estimate effective heights in the point-to-point (site-specific) mode, the ITM utilizes least squares fitting to a portion of the terrain profile, and a comprehensive path profile analysis. The portion of the profile utilized depends on whether or not the direct ray's elevation has terrain clearance. If the path is line-of-sight (LOS), the least squares fit is applied to the central 80% of the terrain elevations between the terminals, yielding a single linear function with distance, extrapolated to each terminal's endpoint to estimate its effective height. If the path is transhorizon, a least squares fit is applied to the central 80% of the terrain elevations between each terminal and its corresponding radio horizon distance. For both paths, each of the terminals' effective heights is always limited to be at least the corresponding height above ground of the radiation center.

For any given transhorizon path, polarization, and frequency of operation, the net effect of increasing the effective heights is to reduce ITM's predicted reference attenuation. The converse is also valid, but reductions in the effective heights are limited to the corresponding terminals' heights above ground. However, for any given LOS path, polarization, and frequency of operation, the possibility of constructive and destructive "interference" effects between the direct ray and the ray reflected from the ground may or may not reduce ITM's predicted reference attenuation as the terminals' effective heights increase, up to a point. Beyond that point, increasing the terminals' effective heights will lead to reductions in ITM's predicted reference attenuation.

Previous comparison studies of measured propagation data and ITM's point-to-point mode predictions have indicated that, in some cases, the algorithm tends to overestimate the terminals' effective heights. This is true of the datasets with low terminal radiation center heights above ground. However, examination of individual measurement data and predictions indicated that, for many of these, an effective height estimate greater than the radiation center height above ground improved ITM's prediction accuracy, compared to substitution of the radiation center height above ground for the effective height. Figures 1 and 2 show examples of how different the predictions can be for the two cases. In some, the effective height that improved the prediction accuracy exceeded the existing algorithm's estimate. Also found were instances where improved prediction accuracy would result if the terminals' effective heights were less than the radiation center heights above ground.

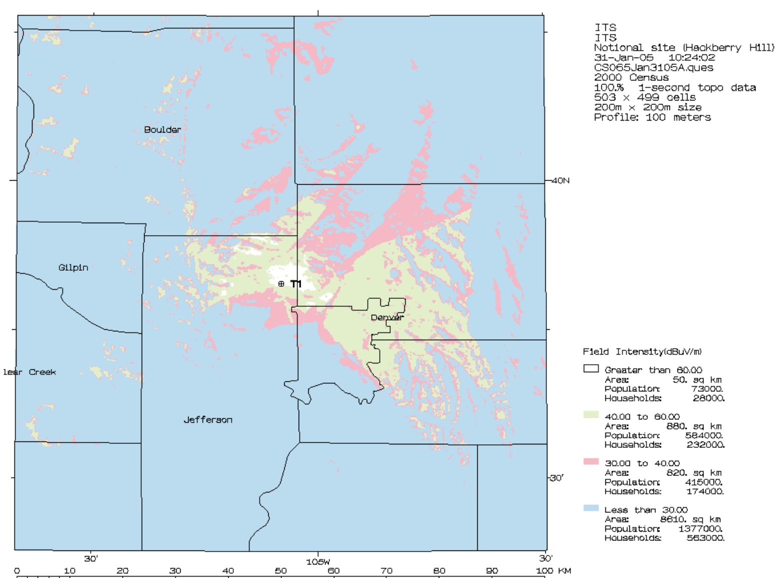

Figure 1. CSPM plot showing predicted radio coverage using ITM with the existing effective height algorithm.

The preceding discussion suggests that the effective height algorithm in ITM can be improved. However, key aspects should be retained, e.g., the subdivision of paths into LOS and transhorizon classifications, and the rule that any adjustments or limitations to the effective heights apply equally to both terminals. The latter condition is necessary to preserve reciprocity. Unfortunately, it limits the range of improvement in the prediction accuracy, because if one terminal is high while the other is low, the effective height of the low terminal is more influential on the prediction accuracy.

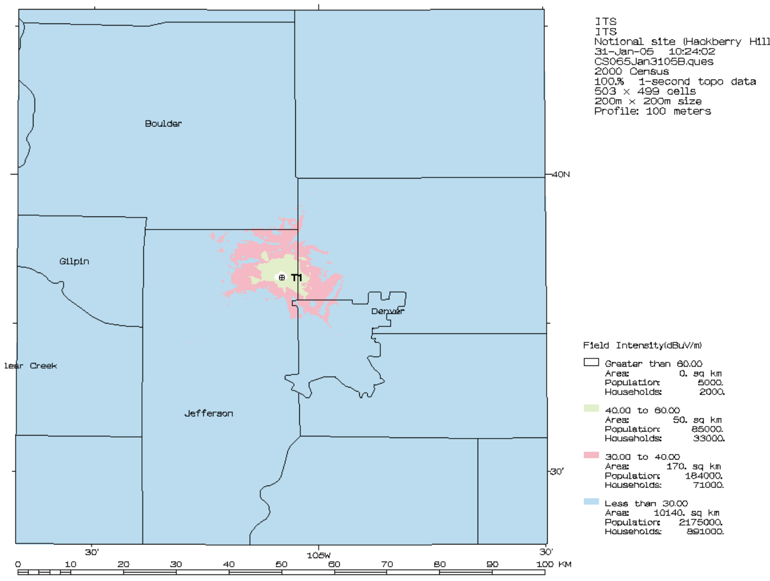

Figure 2. CSPM plot showing predicted radio coverage using ITM with effective heights set to the structural height above ground.

Two approaches to defining the terminals' effective heights have been studied thus far. Both are motivated by determining an effective ground reflection point and least squares fitting portions of the terrain profile centered on this point. The first approach was to search the terrain profile, or portion thereof, depending upon whether or not the path was LOS or transhorizon, for the point or points of reflection, based on the assumption that the terrain elevation followed a straight line with distance between any two adjacent profile points. A further condition was applied to each point detected: it must be intervisible to both terminals. We therefore label this the "glint" approach. Depending on whether no glint, one glint, or more than one glint was detected, varying portions of the terrain profile, centered on the glint or glints, were then least squares fitted and the resulting line or lines were extrapolated to the terminals' locations to estimate the effective heights. If no glint was detected, the method defaulted to the existing effective height algorithm. Unfortunately, many of the paths had no detected glint, so this approach demonstrated no or only very limited improvement.

A second approach was therefore devised that searched the terrain profile, or portions thereof, depending upon whether or not the path was LOS or transhorizon, for the point of minimum clearance for the first Fresnel zone. For LOS paths, the first Fresnel zone was referenced to the direct ray between the terminals' heights above ground. For transhorizon paths, the first Fresnel zone was referenced to the ray between the terminal's height above ground and the terrain obstacle comprising its corresponding radio horizon. We thus label this the "minimum clearance" approach. Varying sections of the terrain profile were then least squares fitted and the resulting straight line or lines extrapolated to the terminals' locations to estimate the corresponding effective heights. The results of this approach usually improved the mean prediction accuracies. Although this approach is more robust, it is also suboptimal, because the prediction accuracies' standard deviations were often increased when compared to the existing effective height algorithm. Furthermore, when compared to either the means or the standard deviations of the prediction accuracies for the effective heights set at the terminals' heights above ground, there was no improvement in the prediction accuracies' statistics.

Additional effort to improve on the existing effective height algorithm is plainly required. Limiting the terminals' effective heights may help to reduce the minimum clearance approach's prediction accuracies' (absolute values of the) means and standard deviations. However, these limits must be reciprocal for the algorithm to have wider utility and applicability.

For more information, contact:
Paul M. McKenna
(303) 497-3474
e-mail pmckenna@its.bldrdoc.gov